Notice No.3

Rules for the Manufacture, Testing and Certification of Materials July 2016

The status of this Rule set is amended as shown and is now to be read in conjunction with this and prior Notices. Any corrigenda included in the Notice are effective immediately.

Please note that corrigenda amends to paragraphs, Tables and Figures are not shown in their entirety.

Issue date: June 2017

Amendments to	Effective date	Mandatory Instrument
Chapter 1, Section 6	Corrigenda	N/A
Chapter 2, Section 2	1 July 2017	N/A
Chapter 3, Sections 1, 2, 3, 9 & 10	1 July 2017	N/A
Chapter 4, Section 1	1 July 2017	N/A
Chapter 7, Section 5	1 July 2017	N/A
Chapter 10, Sections 2, 3 & 4	1 July 2017	N/A
Chapter 11, Sections 1, 3, 4, 5, 7 & 8	1 July 2017	N/A
Chapter 12, Sections 2 & 5	1 July 2017	N/A
Chapter 13, Sections 1 & 5	1 July 2017	N/A
Chapter 14, Section 3	Corrigenda	N/A
Chapter 15, Section 2	1 July 2017	X

Chapter 1
General Requirements

■ *Section 6*
References

6.1 General

6.1.1 The location of National and International Standards referenced in these Rules are shown in *Table 1.6.1 List of National and International Standards*. The latest version of the standards in this table applies unless otherwise agreed.

Table 1.6.1 List of National and International Standards

Rule reference	Standard
Chapter 1 – General Requirements	ISO 9001: 2005 SNT-TC-1A, 2011 ISO 9712:2012
Chapter 2 – Testing Procedures for Metallic Materials	ISO 6892-1: 2009 ISO 6892-2:2009 ISO 185: 2005 ISO 2566-1: 1999 ISO 148-1: 2010 ISO 7500-1: 2015 ISO 6506-1: 2014 ISO 6506-2: 2014 ISO 6506-3: 2014 ISO 6507-1: 2006 ISO 6507-2: 2006 ISO 6507-3: 2006 ISO 6508-1: 2015 ASTM E23-Rev C (2012)
Chapter 3 – Rolled Steel Plates, Strip, Sections and Bars	EN 10160: 1999 ASTM A578-07 (2012) ASTM E112 – 2013 ASTM E381-01 (2012) ASTM A255-2010 ISO 7452:2013 ASTM E208-06 (2012) JWES2815
Chapter 4 – Steel Castings	ISO 1161: 1984/Amendment 1: 2007
Chapter 5 – Steel Forgings	ASTM E112 (2013)
Chapter 8 – Aluminium Alloys	ASTM G66 (2013) ASTM G67 (2013)
Chapter 9 – Copper Alloys	ASTM E272-2015 EN 1057: 2006 +A1: 2010
Chapter 10 – Equipment for Mooring and Anchoring	ISO 1704: 2008 ISO 1834: 1999 BS 7160 (R2002) ASTM E112 (2013) ASTM E381-01 (2012) ASTM A255-2010
Chapter 11 – Approval of Welding Consumables	ISO 3690: 2012 ISO 10042: 2005 ASTM G48 – 11
Chapter 12 – Welding Qualifications	ISO 6947: 2011 ISO 5817: 2014 ISO 6520-1: 2007 ISO 6507-1: 2005 ISO 10042: 2005 ASTM G48-11 ISO 25239-3: 2011 ISO 25239-4: 2011
Chapter 13 – Requirements for Welded Construction	ISO 9712:2012 ISO 25239-5: 2011 ISO 6520-1: 2007 SNT TC-1A-2011 AWS D3.6M:2010 ISO 10042: 2005
Chapter 14 – Plastics Materials	ISO 527-2: -2012 ISO 178: 2010 Amd 1:2013 ISO 62: 2008 ISO 75-2: 2013 ISO 604: 2002 ISO 527-4: 1997 ISO 14125: 1998/amd1:2011

	ISO 14130: 1997/corr1:2003 ~~ISO 1172: 1996~~ ISO 1922- 2012 ASTM C273/C273M -11 ASTM C393/C393M -11e1 ISO 845- 2006 ~~ASTM C297~~/C297M-04 (2010) ISO 844-2014 ISO 180-2000/Amd 2:2013 ASTM D2583-13a BS 2782-10 Method 1001: 1977 ~~ISO 175: 2016~~

Table 1.6.1 List of National and International Standards

Rule reference	Standard
Chapter 1 – General Requirements	ISO 9001 SNT-TC-1A ISO 9712
Chapter 2 – Testing Procedures for Metallic Materials	ISO 6892-1 ISO 6892-2 ISO 185 ISO 2566-1 ISO 148-1 ISO 7500-1 ISO 6506-1 ISO 6506-2 ISO 6506-3 ISO 6507-1 ISO 6507-2 ISO 6507-3 ISO 6508-1 ASTM E23
Chapter 3 – Rolled Steel Plates, Strip, Sections and Bars	EN 10160 ASTM A578-07 ASTM E112 ASTM E381-01 ASTM A255 ISO 7452 ASTM E208-06 JWES2815
Chapter 4 – Steel Castings	ISO 1161
Chapter 5 – Steel Forgings	ASTM E112
Chapter 8 – Aluminium Alloys	ASTM G66 ASTM G67
Chapter 9 – Copper Alloys	ASTM E272 EN 1057
Chapter 10 – Equipment for Mooring and Anchoring	ISO 643 ISO 1704 ISO 1834 BS 7160 ASTM E112 ASTM E381 ASTM A255
Chapter 11 – Approval of Welding Consumables	ISO 3690 ISO 10042 ASTM G48
Chapter 12 – Welding Qualifications	ISO 6947 ISO 5817 ISO 6520-1 ISO 6507-1 ISO 10042 ASTM G48 ISO 25239-3 ISO 25239-4
Chapter 13 – Requirements for Welded Construction	ISO 9712 ISO 25239-5 ISO 6520-1 SNT TC-1A AWS D3.6M ISO 10042
Chapter 14 – Plastics Materials	ISO 527-2 ISO 178 ISO 62 ISO 75-2 ISO 604 ISO 527-4 ISO 14125 ISO 14130 ISO 1172 ISO 1922 ASTM C273/C273 ASTM C393/C393 ISO 845 ASTM C297/C297M ISO 844 ISO 180 ASTM D2583-13a BE EN 59 ISO 175

Chapter 2
Testing Procedure for Metallic Materials

■ *Section 2*
Tensile tests

2.1 Dimensions of test specimens

2.1.6 For plates, strip and sections, the test specimens are to be machined to the dimensions shown in *Figure 2.2.3 Test specimen dimensions for plates, strip and sections - I and aluminum alloys* or *Figure 2.2.4 Test specimen dimensions for plates, strip and sections - II*. Where the capacity of the available testing machine is insufficient to allow the use of a test specimen of full thickness, this may be reduced by machining one of the rolled surfaces. Alternatively, for materials over 40 mm thick, test specimens of circular cross-section machined to the dimensions shown in *Figure 2.2.1 Test specimen dimensions for forgings and castings - I* may be used. The axes of these test specimens are to be located at approximately one quarter of the thickness from one of the rolled surfaces as shown in *Figure 3.1.2 Position of test material*.

Chapter 3
Rolled Steel Plates, Strip, Sections and Bars

■ *Section 1*
General requirements

1.1 Scope

1.1.4 Plates, strip, sections and bars are to be manufactured and tested in accordance with the requirements of *Ch 1 General Requirements* and *Ch 2 Testing Procedures for Metallic Materials*, the general requirements of this Section and the appropriate specific requirements given in Sections *Ch 3, 2 Normal strength steels for ship and other structural applications*. Steels differing from the requirements of these Sections in respect of chemical composition, deoxidation practice, condition of supply or mechanical properties may be accepted subject to special approval by LR. Such steels are to be given a special designation, *see Ch 3, 1.11 Identification of materials*.

1.8 Test material and mechanical tests

(*Part only shown*)

1.8.4 Test material is to be taken from the following positions:

(f) ~~For plates and flats with thicknesses in excess of 40 mm, full thickness specimens may be prepared, but when instead a machined round specimen is used then the axis is to be located at a position lying one-quarter of the product thickness from the surface as shown in *Figure 3.1.2 Position of test material.*~~ When the capacity of the available testing machine is insufficient, tensile testing is to be carried out in accordance with the requirement of *Ch 2, 2.1 Dimensions of test specimens 2.1.6*.

1.11 Identification of materials

(*Part only shown*)

1.11.1 Every finished item is to be clearly marked by the manufacturer in at least one place with LR's brand "LR" and the following particulars:

(f) Steels which have been specially approved and which differ from the requirements in this Chapter are to have the letter `S' after the agreed identification mark.

■ *Section 2*
Normal strength for ship and other structural applications

2.4 Mechanical tests

~~2.4.14 For batch tested Grade B and D steel plates supplied in a condition other than furnace normalised, with a thickness equal to, or greater than 25 mm and 12 mm respectively, and where the average value of one set of tests is less than 40 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 40 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of *Table 3.2.3 Mechanical properties for acceptance purposes*. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also Ch 3, 2.3 Condition of supply 2.3.2*.~~

Existing paragraph 2.4.15 has been renumbered 2.4.14.

■ *Section 3*
Higher strength steels for ship and other structural applications

~~3.2~~ ~~Alternative specifications~~

~~3.2.1 Steels differing from the requirements of this Section in respect of chemical composition, deoxidation practice, condition of supply or mechanical properties may be accepted subject to special approval by LR. Such steels are to be given a special designation, *see Ch 3, 3.7 Identification of materials 3.7.2*.~~

Existing sub-Sections 3.3 to 3.8 have been renumbered 3.2 to 3.7.

~~3.7~~ 3.6 Identification of materials

~~3.7.2 Steels which have been specially approved and which differ from the requirements of this Section are to have the letter `S' after the agreed identification mark.~~

■ *Section 9*
Bars for welded chain cables

9.1 Scope

9.1.3 For the offshore grades, R3, R3S, R4, R4S and R5, approval is confined to bar to be supplied to a nominated chain manufacturer and will be given only after successful testing of a completed chain. Separate approvals are required if bar is to be supplied to more than one cable manufacturer. Approval of a higher grade does not cover approval of a lower grade, as all grades must be individually approved. If it is demonstrated to the satisfaction of LR that the higher and lower grades are produced to the same manufacturing procedure using the same chemistry and heat treatment, consideration will be given to qualification of a lower grade by a higher grade. The parameters applied during qualification are not to be modified during production.

9.2 Manufacture

9.2.1 All grades of bar material are to be made from killed steel, and, all grades of bar material except for Grade U1 chain cables are to be fine grained. For Grades R3, R3S, R4, R4S and R5 the austenite grain size is to be 6 or finer, in accordance with ASTM E112 or equivalent grain size index in accordance to ISO 643. Measurements for circular sections are to be taken at one-third of the radius.

9.6 Mechanical tests

(*Part only shown*)

Table 3.9.2 Mechanical properties

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
Note 1. Impact tests may be waived when the chain cable is to be supplied in one of the heat treated conditions given in *Table 10.2.3 Condition of supply and scope of mechanical tests for finished chain cables and fittings*. **Note** 2. Testing may be carried out at either 0°C or –20°C, at the option of LR. **Note** 3. The ratio of yield strength to tensile strength should be ~~not exceed~~ 0,92 maximum unless specially approved. **Note** 4. The aim maximum hardness for R4S is to be HB330, and for R5 is to be HB340.							

Existing Section 10 has been deleted in its entirety.

■ *Section 10*
High strength steels for welded structures

10.1 Scope

10.1.1 Provision is made in this Section for hot-rolled, fine-grain treated, weldable high strength structural steels intended for use in marine and offshore structural applications. These requirements are not intended to apply to steels for the hull structure of ships.

10.1.2 The required notch toughness is designated by subdividing the strength levels into Grades AH, DH, EH and FH.

10.1.3 The steels may be supplied in eight strength levels with minimum yield stresses of 420, 460, 500, 550, 620, 690, 890 and 960 N/mm^2 respectively. For yield strength level of 890 and 960 N/mm^2 grade F is not applicable.

10.1.4 Steels covered by the scope of these Rules requirements may be supplied either in the normalised (N), normalising rolled (NR), thermomechanically controlled rolled (TM) or quench and tempered (QT) condition.

10.1.5 The requirements of this Section are primarily intended to apply to plates, wide flats, sections, bars and seamless tubulars, generally not exceeding the thickness limits given in *Table 3.10.1 Maximum Thickness Limits*. Steels with a thickness beyond the maximum thickness as given in *Table 3.10.1 Maximum Thickness Limits* are to be specially considered by LR.

Table 3.10.1 Maximum Thickness Limits

Steel Grade	Condition of supply	Maximum thickness (mm) (*see* Note 1)			
		Plates	Sections	Bars	Tubulars
AH42, AH46 DH42, DH46 EH42, EH46	N	250	50	250	65
	NR	150	(*see* Note 2)		
	TM	150	50	-	-

FH42, FH46	QT	150	50	-	50
AH50, AH55, AH62, AH69 DH50, DH55, DH62, DH69 EH50, EH55, EH62, DE69 FH50, FH55, FH62, FH69	TM	150	-	-	-
	QT	150	-	-	50
AH89 DH89 EH89	TM	100	-	-	-
	QT	100	-	-	-
AH96 DH96 EH96	QT	50	-	-	-
Note 1. Thicknesses in excess of these limits or those indicated by '-' may be considered for approved applications. Note 2. The maximum thickness limits of sections and bars produced by the NR process route are generally lower than those applicable when manufactured by the N route and are subject to special consideration by LR.					

10.2 Manufacture

10.2.1 The steel is to be made to a specification approved by LR which should include the manufacturing procedure, deoxidation practice, heat treatment and mechanical properties.

10.2.2 Vacuum degassing treatment shall be applied for all steels with enhanced through thickness properties and for grades with yield strength level of 690, 890 and 960 N/mm^2.

10.2.3 The steel is to be supplied in the fully killed and fine grain treated condition as detailed in the approved manufacturing specification.

10.3 Chemical composition

10.3.1 The chemical analysis is to be in accordance with the approved manufacturing specification. All the elements listed in *Table 3.10.2 Chemical Composition* are to be reported.

10.3.2 All alloying elements, including residuals, are to be as detailed in the approved manufacturing specification. Where Boron is added, this is not to exceed 0,005 per cent.

10.3.3 The steel shall contain nitrogen binding elements as detailed in the approved manufacturing specification.

Table 3.10.2 Chemical Composition

Chemical Composition	Condition of supply/Steel Grade					
	N/NR		TM		QT	
	AH42 DH42 AH46 DH46	EH42 EH46	AH42 DH42 AH46 DH46 AH50 DH50 AH55 DH55 AH62 DH62 AH69 DH69 AH89	EH42 FH42 EH46 FH46 EH50 FH50 EH55 FH55 EH62 FH62 EH69 FH69 DH89 EH89	AH42 DH42 AH46 DH46 AH50 DH50 AH55 DH55 AH62 DH62 AH69 DH69 AH89 AH96	EH42 FH42 EH46 FH46 EH50 FH50 EH55 FH55 EH62 FH62 EH69 FH69 DH89 EH89 DH96 EH96
Carbon % max	0,20	0,18	0,16	0,14	0,18	
Manganese %	1,0~1,70		1,0~1,70		1,70	
Silicon % max	0,60		0,60		0,80	
Phosphorus % max (*see* Note 1)	0,030	0,025	0,025	0,020	0,025	0,020
Sulphur % max (*see* Note 1)	0,025	0,020	0,015	0,010	0,015	0,010
Aluminium $_{total}$ % min (*see* Note 2)	0,02		0,02		0,018	
Niobium % max (*see* Note 2)	0,05		0,05		0,06	

Vanadium % max (*see* Note 3)	0,20	0,12		0,12		
Titanium % max (*see* Note 3)	0,05	0,05		0,05		
Nickel % max (*see* Note 4)	0,80	2,00 (*see* Note 4)		2,00 (*see* Note 4)		
Copper % max	0,55	0,55		0,50		
Chromium % max (*see* Note 3)	0,30	0,50		1,50		
Molybdenum % max (*see* Note 3)	0,10	0,50		0,70		
Nitrogen % max	0,025	0,025		0,015		
Oxygen ppm max (*see* Note 5)	Not applicable	Not applicable	50	Not applicable	30	
Note 1. For sections the P and S content can be 0,005 per cent higher than the value specified in the Table. **Note** 2. The total aluminium to nitrogen ratio shall be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N-ratio do not apply. **Note** 3. Total Nb+V+Ti ≤ 0,26 % and Mo+Cr ≤0,65%, not applicable for QT steels. **Note** 4. Higher Ni content may be approved at the discretion of LR. **Note** 5. The requirement on maximum Oxygen content is only applicable to DH89; EH89; DH96 and EH96.						

10.3.4 The carbon equivalent value is to be calculated from the ladle analysis using the formula given below. Maximum values are specified in *Table 3.10.3 Maximum Ceq, CET and Pcm values*.

$$\boldsymbol{Ceq = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}}\ (\%)$$

For steel grades H46 and higher, *CET* may be used instead of *Ceq* at the discretion of the manufacturer, and is to be calculated according to the following formula:

$$\boldsymbol{CET = C + \frac{(Mn + Mo)}{10} + \frac{(Cr + Cu)}{20} + \frac{Ni}{40}}\ (\%)$$

For TM and QT steels with carbon content not exceeding 0,12 per cent, the cold cracking susceptibility *Pcm* for evaluating weldability may be used instead of carbon equivalent of *Ceq* or *CET* at the manufacturer's discretion, and is to be calculated using the following formula:

$$\boldsymbol{Pcm = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B}\ (\%)$$

Table 3.10.3 Maximum *Ceq*, *CET* and *Pcm* values

Steel yield strength level/Condition of supply	Ceq (%)						CET (%)	Pcm (%)
	Plates			Sections	Bars	Tubulars	all	all
	t≤50 (mm)	50<t≤100 (mm)	100<t≤250 (mm)	t≤50 (mm)	t≤250 or d≤250	t≤65 (mm)	all	all
H42N/NR	0,46	0,48	0,52	0,47	0,53	0,47	N/A	
H42TM	0,43	0,45	0,47	0,44	N/A	N/A		
H42QT	0,45	0,47	0,49	N/A	N/A	0,46		
H46N/NR	0,50	0,52	0,54	0,51	0,55	0,51	0,25	
H46TM	0,45	0,47	0,48	0,46	N/A	N/A	0,30	0,23
H46QT	0,47	0,48	0,50	N/A	N/A	0,48	0,32	0,24
H50TM	0,46	0,48	0,50	N/A		N/A	0,32	0,24
H50QT	0,48	0,50	0,54	N/A		0,50	0,34	0,25
H55TM	0,48	0,50	0,54	N/A		N/A	0,34	0,25
H55QT	0,56	0,60	0,64	N/A		0,56	0,36	0,28
H62TM	0,50	0,52	N/A	N/A		N/A	0,34	0,26
H62QT	0,56	0,60	0,64	N/A		0,58	0,38	0,30
H69TM	0,56	N/A		N/A		N/A	0,36	0,30
H69QT	0,64	0,66	0,70	N/A		0,68	0,40	0,33
H89TM	0,60	N/A		N/A		N/A	0,38	0,30
H89QT	0,68	0,75	N/A	N/A		N/A	0,40	N/A
H96QT	0,75	N/A				N/A	0,40	N/A
Note: N/A = Not applicable								

10.4 Mechanical tests

10.4.1 For steels in the normalising rolled (NR) or thermomechanically controlled rolled (TM) conditions, one tensile test is to be made for each batch of 25 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast. One set of three Charpy V-notch impact tests specimens are to be taken from each piece. A piece is to be regarded as the rolled product from a single slab or billet, or from a single ingot if this is rolled directly into plates. Charpy V-notch impact test specimens from plates and flats with a finished width more than 600 mm are to have their axes transverse to the main rolling direction.

10.4.2 For normalised (N) and quenched and tempered (QT) plates, one tensile test piece and a set of three Charpy V-notch impact test specimens are to be taken from each plate as heat treated. Charpy V-notch impact test specimens from quenched and tempered plates and flats with a finished width more than 600 mm are to have their axes transverse to the main rolling direction.

10.4.3 For sections, bars and tubulars, one tensile test piece and one set of three Charpy V-notch impact test specimens are to be taken from each batch of 25 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast. For sections, the thickness to be considered is the thickness of the product at the point at which samples are taken for mechanical tests. A piece is to be regarded as the rolled product from a single slab or billet, or from a single ingot if this is rolled directly into sections, bars or tubulars.

10.4.4 For material with a thickness in excess of 50 mm, impact tests shall be taken at the quarter thickness (t/4) location and additionally at mid-thickness (t/2) location. As an alternative to a full thickness or a sub-sized flat tensile specimen, the specimens are to be located at a position lying at a distance of t/4 from the surface and additionally at t/2 for thickness above 100 mm or as near as possible to these positions.

10.4.5 For steels designated with improved through thickness properties, through thickness tensile tests are to be performed in accordance with the requirement of *Ch 3, 8 Plates with specified through thickness properties*. Through-thickness tensile strength is required to be not less than 80 per cent of the specified minimum tensile strength.

10.4.6 The results of the tests are to comply with the appropriate requirements of *Table 3.10.4 Mechanical Properties for acceptance purpose*.

Table 3.10.4 Mechanical Properties for acceptance purpose

Steel grade	Yield Stress N/mm^2 min (*see* Notes 1 and 2)				Tensile Strength N/mm^2				Elongation on $5{,}65\sqrt{S0}$ %min (*see* Note 3)		Charpy V-notch impact test	
	Nominal thickness (mm)										Average energy J Minimum	
	≥3 ≤50	>50 ≤ 100	>100 ≤150	>150 ≤250	≥3 ≤50	>50 ≤ 100	>100 ≤150	>150 ≤250	T	L	T	L
AH42 DH42 EH42 FH42	420	390	365	365	520~680	520~680	470~650	470~650	19	21	28	42
AH46 DH46 EH46 FH46	460	430	390	390	540~720	540~720	500~710	500~710	17	19	31	46
AH50 DH50 EH50 FH50	500	480	440	-	590~770	590~770	540~720	-	17	19	33	50
AH55 DH55 EH55 FH55	550	530	490	-	640~820	640~820	590~770	-	16	18	37	55
AH62 DH62 EH62 FH62	620	580	560	-	700~890	700~890	650~830	-	15	17	41	62

AH69 DH69 EH69 FH69	690	650	630	-	770~940	770~940	710~900	-	14	16	46	69
AH89 DH89 EH89	890	830	-	-	940~1100	940~1100	-	-	11	13	46	69
AH96 DH96 EH96	960	-	-		980~1150	-	-	-	10	12	46	69

Symbols

T = Transverse
L = Longitudinal

Notes

Impact tests are to be made on the various grades at the following temperatures:

AH grades 0°C
DH grades -20°C
EH grades -40°C
FH grades -60°C

Note 1. For tensile test either the upper yield stress (ReH) or where ReH cannot be determined, the 0,2 per cent proof stress (Rp0,2) is to be determined.
Note 2. The ratio of actual yield strength to tensile strength shall not exceed 0,94. A higher yield strength to tensile strength ratio may be acceptable on a project specific basis, subject to special consideration.
Note 3. For full thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm the elongation is to comply with the minimum values shown in *Table 3.10.5 Elongation minimum values for a width of 25 mm and a 200 mm gauge length*.

Table 3.10.5 Elongation minimum values for a width of 25 mm and a 200 mm gauge length

Thickness (mm) (*See* Note 1)		≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤40	>40 ≤50	>50 ≤70
Elongation (%)	Strength levels							
	H42	11	13	14	15	16	17	18
	H46	11	12	13	14	15	16	17
	H50	10	11	12	13	14	15	16
	H55	10	11	12	13	14	15	16
	H62	9	11	12	12	13	14	15
	H69 (*see* Note 2)	9	10	11	11	12	13	14
	H89 H96	*See* Note 3						

Note 1. The tabulated elongation minimum values are the requirements for testing specimen in transversed direction.
Note 2. Re-test can be carried out on the standards proportional test specimen with a gauge length of L_0=5,65 $\sqrt{S_0}$ to meet the requirement of *Table 3.10.4 Mechanical Properties for acceptance purpose* when the elongation does not meeting the requirement in this table. *See Ch 2, 2.4 Equivalent elongations*.
Note 3. Steel with strength level of 89 and 96 shall be tested by proportional specimens with a gauge length of L_0=5,65 $\sqrt{S_0}$.

10.5 Identification of materials

10.5.1 The particulars detailed in *Ch 3, 1.11 Identification of materials* are to be marked on each piece which has been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint.

10.6 Certification of materials

10.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in *Ch 3, 1.12 Certification of materials* and, additionally, are to state the specified maximum *Ceq*, *CET* or *Pcm*. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in *Table 3.10.2 Chemical composition*.

Chapter 4
Steel Castings

■ *Section 1*
General requirements

1.9 Rectification and dressing of castings

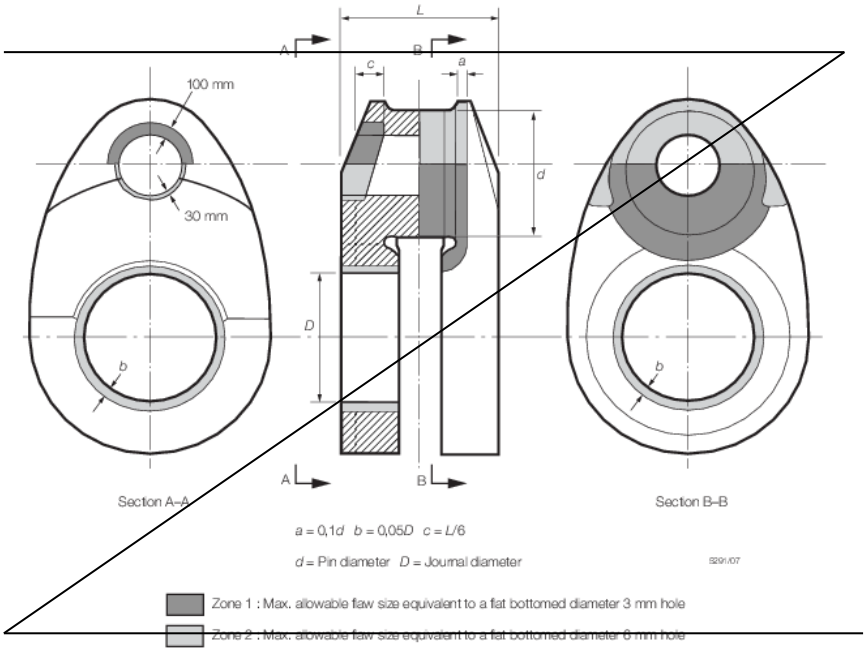
1.9.5 A statement and/or sketch detailing the extent and position of all welds is to be prepared by the manufacturer. Copies of these sketches are to be submitted to LR~~, and copies are to be attached to the certificates for the castings~~.

Chapter 7
Iron Castings

■ *Section 5*
Iron castings for crankshafts

5.5 Non-destructive examination

~~5.5.4 Each casting is to be examined by ultrasonic testing, and the extent of examination and defect acceptance criteria, using the DGS (Distance Gain Size) technique, are to be as shown in ` 789. Alternative ultrasonic procedures may be submitted for review.~~



~~Figure 7.5.1 Ultrasonic examination acceptance levels~~

Chapter 10
Equipment for Mooring and Anchoring

■ *Section 2*
Stud link chain cables for ships

2.1 Scope

2.1.3 The design of chain cables and fittings is to be to a Standard recognised by LR, such as ISO 1704.

2.7 Welding of studs

2.7.2 The stud ends must be a good fit inside the link, and the weld is to be confined to the stud end opposite the flash-butt weld. Welding of studs both ends is not permitted unless specially approved. The full periphery of the stud end is to be welded. If, however, it can be demonstrated to the Surveyor that the quality of welding is of a high standard then partial peripheral welding may be accepted provided that welds are made only at the sides of the stud and that each run extends continuously for at least 25 per cent of the stud periphery. Weld start/stop positions are not to be located in the plane of the chain cable.

2.7.5 All stud welds are to be visually inspected. At least one stud weld within each length of cable is to be inspected using magnetic particle inspection or dye penetrant testing in accordance with *Ch 1, 5 Non-destructive examination* after the chain has been proof loaded. If a crack is found, the stud welds in the adjoining links are to be inspected; if a crack is found in either link, all the stud welds in that length are to be inspected using magnetic particle inspection or dye penetrant testing.

2.11 Dimensional inspection

2.11.8 The form and proportion of links and shackles are to be in accordance with a standard recognised by LR, such as ISO 1704, *see Figure 10.2.2 Common link* to *Figure 10.2.9 Lugless shackle of the Kenter type*; alternatively, the design may be specifically approved by LR.

■ *Section 3*
~~Stud link mooring~~ Offshore Mooring chain cables

3.1 Scope

3.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5, of stud link chain and studless flash butt welded chain cable intended for offshore mooring applications such as mooring of mobile offshore units, mooring of floating production units, offshore loading systems and gravity based structures during fabrication. Special consideration will be given to the use of grades outside the existing scope.

3.1.2 Design of stud link chain cables must be to a recognised Standard, such as ISO 1704~~; alternatively, the design may be specifically approved by LR~~. For studless chain the shape and dimensions are to comply with the requirements of this Section. Non-Standard designs of chain are to be subject to special consideration, and may require a fatigue analysis and tests to confirm relevant performance.

3.1.4 The studless link chain is generally expected to be deployed only once, being intended for long-term mooring applications with a pre-determined service life.

3.2 Manufacture

3.2.1 All grades of chain cable and ~~accessories~~ fittings are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers for ~~stud link~~ offshore mooring chain cables is published separately by LR.

~~3.2.2 The works in which the chain is manufactured is to have a quality system approved by LR. The provision of such a quality system is required in addition to and not in lieu of the witnessing of tests by a Surveyor.~~

Existing paragraphs 3.2.2 to 3.2.5 have been renumbered 3.2.2 to 3.2.4.

~~3.2.6~~ 3.2.5 Bar material may be heated ~~either~~ by electric resistance, induction or in a furnace. For electrical resistance heating or induction heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control and the temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and records taken.

~~3.2.7~~ 3.2.6 The following welding parameters (as approved in the weld procedure) are to be controlled during welding of each link:

(a) platen motion;
(b) current as a function of time; and
(c) hydraulic pressure.

The controls are to be checked at least once every four hours~~.~~ and records taken.

Existing paragraphs 3.2.8 and 3.2.9 have been renumbered 3.2.7 and 3.2.8.

~~3.3 Dimensions and tolerances~~

~~3.3.1 The form and proportions of links and shackles are to be in accordance with ISO/1704, *see Figure 10.2.2 Common link*. Link tolerances are to be in accordance with *Ch 10, 3.3 Dimensions and tolerances 3.3.2.*~~

~~3.3.2 Diameter measured at the crown:~~

~~Minus 1 mm when $d_e \leq 40$ mm~~

~~Minus 2 mm when 40 mm $< d_e \leq 84$ mm~~

~~Minus 3 mm when 84 mm $< d_e \leq 122$ mm~~

~~Minus 4 mm when 122 mm $< d_e \leq 152$ mm~~

~~Minus 6 mm when 152 mm $< d_e \leq 184$ mm~~

~~Minus 7,5 mm when 184 mm $< d_e \leq 210$ mm~~

~~For diameters of 20mm or greater, the plus tolerance on the diameter at the crown measured perpendicular to the plane of the link, d_p, is not to exceed 5 per cent, and the cross-sectional area at the crown is to have no negative tolerance. For diameters less than 20mm, the plus tolerance is to be agreed between the chain manufacturer and bar material supplier.~~

~~3.3.3 The diameter measured at locations other than the crown is to have no negative tolerance. For diameters of 20mm or greater, the plus tolerance may be up to 5 percent of the nominal diameter except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR. For diameters less than 20mm, the plus tolerance is to be agreed between the chain manufacturer and bar material supplier.~~

~~3.3.4 The maximum allowable tolerance on a length of five links measured in accordance with *Ch 10, 2.11 Dimensional inspection 2.11.1* is +2,5 per cent. No under-tolerance is permitted.~~

~~3.3.5 A manufacturing tolerance on all other dimensions of ±2,5 per cent is acceptable subject to all parts fitting properly together.~~

~~3.3.6 The tolerances for common links are to be measured in accordance with *Table 10.3.2 Stud link chain cable common link tolerances*.~~

~~3.3.7 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.~~

~~3.3.8 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The tolerances in accordance with *Table 10.3.2 Stud link chain cable common link tolerances* are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.~~

~~3.4~~ 3.3 Studs

~~3.4.1~~ 3.3.1 The studs are to be made of steel corresponding to that of the chain or in compliance with a specification approved by LR. In general, the carbon content should not exceed ~~0.23~~ 0,23 per cent if the studs are to be welded in place.

Existing paragraph 3.4.2 has been renumbered 3.3.2.

~~3.4.3~~ 3.3.3 In all cases where studs are welded into links, this is to be carried out in accordance with *Ch 10, 2.7 Welding of studs*. The visual and NDE inspection of the stud welds is to be carried out in accordance with *Ch 10, 3.6 Proof load tests and non-destructive examination*.

Existing paragraph 3.4.4 has been renumbered 3.3.4.

~~3.4.5 All stud welds are to be visually inspected. At least 10 per cent of all stud welds within each length of chain are to be examined by magnetic particle inspection after proof load testing. Stress raising defects such as cracks, lack of fusion, gross porosity, and undercuts exceeding 1 mm are not permitted; if any such defects are found, then all stud welds in that length of chain are to be examined by means of magnetic particle inspection.~~

Existing paragraph 3.4.6 has been renumbered 3.3.5.

~~3.5~~ 3.4 Heat treatment of completed chain cables

Existing paragraph 3.5.1 has been renumbered 3.4.1.

~~3.5.2~~ 3.4.2 The chains are to be heat treated in a continuous furnace; batch heat treatment is not permitted unless specially approved.

Existing paragraph 3.5.3 has been renumbered 3.4.3.

~~3.5.4~~ 3.4.4 Heat treatment is to be carried out prior to the proof loading ~~and~~, breaking tests and sample mechanical tests.

~~3.5.45~~ 3.4.5 ~~Calibration of furnaces is to be verified by measurement and recording of actual link temperature (surface and internal).~~ The heat treatment furnace is to be properly constructed, efficiently maintained and has adequate means of temperature control. Calibration of furnaces is to be verified by measurement and recording of a calibration test piece with dimensions equivalent to the maximum size of link manufactured.

~~3.6~~ 3.5 Testing of completed chain cables

~~3.6.1~~ 3.5.1 All chain cables are to be ~~tested~~ subjected to proof load tests, non-destructive examination, sample break load tests and sample mechanical tests after final heat treatment in the presence of a Surveyor~~, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR~~. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

3.5.2 The chain is to be shot or sand-blasted prior to testing in order to ensure that its surfaces are free from scale, paint or other coating for inspection and have a suitably prepared surface in accordance with the NDE standard applied.

3.5.3 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with *Ch 1, 5 Non-destructive examination*.

3.6 Proof load tests and non-destructive examination

~~3.6.2~~ 3.6.1 The entire length of chain cable is to be subjected to a proof loading test ~~in an~~ at a ~~approved testing machine~~ Proving Establishment recognised by LR. A list of recognised Proving Establishments is published in the Class Direct section of LR's website, http://www.lr.org. ~~and~~ The chain cable is to withstand the load given in *Table ~~10.3.2~~ 10.3.1 Test loads for mooring chain cables* for the appropriate grade and size of cable.

Table ~~10.3.2~~ 10.3.1 Test loads for mooring chain cables

~~3.6.3~~ 3.6.2 Care should be taken to obtain a uniform stress distribution in the links being tested.

~~3.6.4 The chain is to be shot or sand blasted prior to testing in order to ensure that its surfaces are free from scale, paint or other coating for inspection.~~

~~3.6.5~~ 3.6.3 On completion of the proof load test, each link is to be visually examined and is to be free from significant defects such as mill defects, surface cracks, dents and cuts, especially where gripped by clamping dies during flash butt welding. Studs are to be securely fastened and any burrs, irregularities and rough edges are to be removed by careful grinding. In order to ensure adequate inspection, the chain is to be positioned to facilitate access to all surfaces.

~~3.6.6~~ 3.6.4 All flash butt welds, including the area gripped by the clamping dies on every link, plus 10 per cent of links on all accessible surfaces, are to be examined by magnetic particle inspection in accordance with standards recognized by LR, using wet continuous fluorescent magnetization technique. Non-fluorescent techniques can be accepted in special cases where the standard inspection procedures are impractical. The inspected area is to be free from cracks, lack of fusion, gross porosity, and any ~~other stress concentrations.~~ imperfections with the following maximum allowable dimensions:

- relevant linear indications exceeding 1,6 mm in transverse direction;
- relevant linear indications exceeding 3,2 mm in longitudinal direction;
- relevant non-linear indications exceeding 4,8 mm.

~~3.6.7~~ 3.6.5 Surface defects in the region of the flash butt welds may be removed by grinding, provided that the depth of grinding does not exceed five per cent of the link diameter and is smoothly contoured into the surrounding material. The final dimensions are still to conform with the agreed standard.

~~3.6.8~~ 3.6.6 All flash butt welds on every link are also to be examined by ultrasonic testing in accordance with standards recognised by LR using appropriate scanning techniques designed to detect all expected defects, including any defects within the relevant fusion zones ~~inspection and are to be free from defects such as internal cracks or lack of fusion~~. The flash butt weld must be free from defects causing ultrasonic back reflections equal to or greater than the calibration standard. The single probe technique has limitations as far as testing of the central region is concerned and the flash butt weld imperfections such as flat spots may have poor reflectivity. Where it is deemed necessary, detectability of imperfections may need to be carried out by using a tandem technique, TOFD (Time-of-flight diffraction) or PAUT (phased array ultrasonic testing).

3.6.7 Stud welds, if used, are to be visually inspected. The toes of the fillets are to have a smooth transition to the link with no undercuts exceeding 1,0 mm. In addition, at least 10 per cent of the stud welds distributed through the length is to be magnetic particle

or dye penetrant tested in accordance with standards recognised by LR. Cracks, lack of fusion or gross porosity are not acceptable. If defects are found, testing is to be extended to all stud welds in that length of chain.

~~3.6.9 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with *Ch 1, 5 Non-destructive examination*.~~
~~3.6.10All non-destructive examination operators are to be qualified to a minimum Level II, qualified in accordance with a recognised standard.~~

3.6.8 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in *Ch 10, 3.8 Breaking load tests 3.8.1* and *Ch 10, 3.8 Breaking load tests 3.8.2*. If either of these samples fails, the proof loaded length of cable is not to be accepted.

3.6.9 In the event that two or more links break during the proof load testing, the proof loaded length is to be rejected.

3.6.10 In all cases when a link breaks during the proof load testing, a thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected and also the possibility that similar factors to those which caused the failure may also be present in other parts of the cable, or other chain cables, i.e.:

- Where multiple chains are produced simultaneously, it is recognised that the preceding flash butt welded link and subsequent flash butt welded link will be on an alternative chain length or the other end of the chain length. In such cases, LR may require that two additional break tests are to be taken from the lengths of chain that include the preceding and subsequent welded links.
- If the investigation identifies defects in the flash butt weld or a lower strength flash butt weld is found, additional NDE is to be carried out to identify if other links are affected. A full assessment of the flash butt welding machine it to be carried out, together with assessment of the condition of the bar ends prior to welding.
- The Surveyor is to be advised in advance of all examinations, with reasonable notice being given.

1.7 Dimensional inspection

~~3.6.11~~ 3.7.1 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links, to ensure that the chain meets the tolerances given in ~~*Ch 10, 2.11 Dimensional inspection 2.11.12*~~ *Ch 10, 3.7 Dimensional inspection 3.7.3*. The measurements are to be made while the chain is loaded to ~~about~~ 5-10 per cent of the minimum proof load.

Existing paragraph 3.6.12 has been renumbered 3.7.2.

3.7.3 The maximum allowable tolerance on a length of five links measured in accordance with *Ch 10, 3.7 Dimensional inspection 3.7.1* is +2,5 per cent. No under-tolerance is permitted.

Existing paragraph 3.6.13 has been renumbered 3.7.4.

~~3.6.14 Loads used for plastic straining to set studs are not to exceed those approved in qualification tests.~~

Existing paragraph 3.6.15 has been renumbered 3.7.5.

3.7.6 A manufacturing tolerance on all other dimensions of ±2,5 per cent is acceptable subject to all parts fitting properly together.

3.7.7 The form and proportions of links are to be in accordance with ISO1704, *see Figure 10.2.2 Common link*. Link tolerances are to be in accordance with *Ch 10, 3.7 Dimensional inspection 3.7.3* to *Ch 10, 3.7 Dimensional inspection 3.7.10*.

The negative tolerance on the nominal diameter measured at the crown is not to exceed the following:
Minus 1 mm when $d_c < 40$ mm
Minus 2 mm when 40 mm $< d_c < 84$ mm
Minus 3 mm when 84 mm $< d_c < 122$ mm
Minus 4 mm when 122 mm $< d_c < 152$ mm
Minus 6 mm when 152 mm $< d_c < 184$ mm
Minus 7,5 mm when 184 mm $< d_c < 222$ mm
For diameters of 20 mm or greater, the plus tolerance on the diameter at the crown measured perpendicular to the plane of the link, d_p, is not to exceed 5 per cent. For diameters less than 20 mm, the plus tolerance is to be agreed between the chain manufacturer and bar material supplier.

3.7.8 The cross-sectional area at the crown is to be calculated using the average of the measured diameters, which are to be taken from at least two locations approximately 90 degrees apart. The cross-sectional area at the crown is to have no negative tolerance.

3.7.9 The diameter measured at locations other than the crown is to have no negative tolerance. For diameters of 20 mm or greater, the plus tolerance may be up to 5 per cent of the nominal diameter except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR. For diameters less than 20 mm, the plus tolerance is to be agreed between the chain manufacturer and bar material supplier.

~~3.6.16~~ 3.7.10 If any link fails to meet the above dimensional tolerance requirements ~~(*see Ch 10, 3.3 Dimensions and tolerances*)~~, measurements are to be made on 20 more links on each side of the affected link. If failure to meet any particular dimensional requirements occurs in more than two of the measured links, then all the links are to be dimensionally checked.

~~3.6.17~~ 3.7.11 Should any link be found to be defective or fail to meet the dimensional tolerance requirements or if a five link length of chain exceeds the specified tolerance, the unsatisfactory links are to be removed from the chain and connecting common links complying with the requirements of *Ch 10, ~~3.7~~ 3.10 Connecting common links or substitute links* inserted in their places. Proposals for other methods of repair must be subject to approval by LR and the purchaser. Weld repair of chain is not permitted.

3.7.12 The tolerances for common links are to be measured in accordance with *Table 10.3.2 Stud link chain cable common link tolerances* and *Table 10.3.3 Studless link chain cable common link tolerances.*

Existing paragraphs 3.6.18 and 3.6.19 have been renumbered 3.7.13 and 3.7.14.

~~3.6.20 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in *Ch 10, 3.6 Testing of completed chain cables 3.6.21* and *Ch 10, 3.6 Testing of completed chain cables 3.6.21*. If either of these samples fails, the proof loaded length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected and also the possibility that similar factors to those which caused the failure may also be present in other parts of the cable, or other chain cables. The Surveyor is to be advised in advance of all examinations, with reasonable notice being given.~~

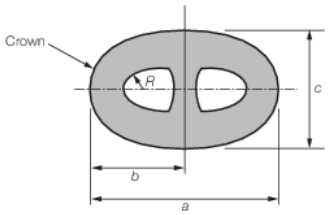
3.7.15 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

3.7.16 For stud link chain, studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The tolerances in accordance with *Table 10.3.2 Stud link chain cable common link tolerances* are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

3.7.17 Chain dimensions are to be recorded and the information retained on file.

Table ~~10.3.1~~ 10.3.2 Stud link chain cable common link tolerances

The internal link radii (*R*) and external radii should be uniform



Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link half length	*a**/2	0,10*d*	0,10*d*
c	Link width	3,6*d*	0,09*d*	0,09*d*
e	Stud angular misalignment	0 degrees	4 degrees	4 degrees
R	Inner radius	0,65*d*	0	—

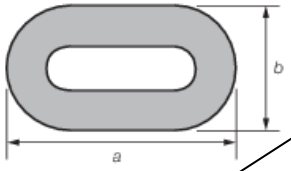
Symbols

d = nominal diameter of chain

a* = actual link length

~~**Table 10.4.1 Studdless chain cable common link tolerances**~~

The internal link radii (*R*) and external radii should be uniform



Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link width	3,35*d*	0,09*d*	0,09*d*
R	Inner radius	0,60*d*	0	—

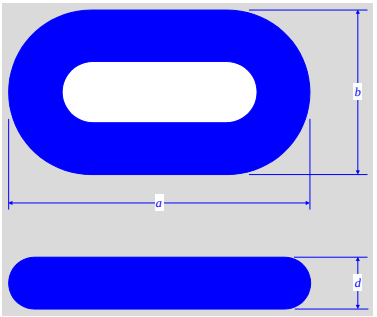
Symbols

d = nominal diameter of chain

Note Other dimensional ratios are subject to special approval.

Table 10.3.3 Studless link chain cable common link tolerances

The internal link radii ® and external radii should be uniform



Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link width	3,35*d*	0,09*d*	0,09*d*
R	Inner radius	0,60*d*	0	–

Symbols

d = nominal diameter of chain

Note Other dimensional ratios are subject to special approval.

3.8 Breaking load tests

~~3.6.21~~ 3.8.1 In addition to the requirements of *Ch 10, ~~3.6 Testing of completed chain cables 3.6.2~~ 3.6 Proof load tests and non-destructive examination 3.6.1*, three link samples are to be selected by the Surveyors from the completed chain for breaking tests. The number of tests required is to be in accordance with *Table 10.3.~~34~~ Frequency of break and mechanical tests*. Extra links are to be provided for the mechanical tests detailed in *Ch 10, ~~3.6 Testing of completed chain cables 3.6.25~~ 3.9 Mechanical tests 3.9.1*. All test links are to be made as part of the chain cable and are to be heat treated with it. These may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents prior to selection of the mechanical test specimens. They are to be properly identified with the length of chain they represent.

~~3.6.22~~ 3.8.2 Breaking test specimens are to withstand the load given in *Table ~~10.3.2~~ 10.3.1 Test loads for mooring chain cables* for the appropriate grade and size of cable for a period of 30 seconds. The specimen is considered to have passed this test if it has shown no sign of fracture and must not crack in the flash butt weld after application of the required load.

Existing paragraph 3.6.23 has been renumbered 3.8.3.

3.8.4 For chain diameters over 100 mm, alternative break-test proposals to the above break-test will be considered whereby a one link specimen is used. Alternatives are to be approved by LR; every heat is to be represented, the test frequency is to be in accordance with *Table 10.3.4 Frequency of break and mechanical tests*, and it is to be demonstrated that the alternative test represents an equivalent load application to the three link test.

~~3.6.24~~ 3.8.5 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

(*Part only shown*)

Table ~~10.3.3~~ 10.3.4 Frequency of break and mechanical tests

Nominal chain diameter mm	Maximum sampling interval m (*See* Note)
187-19~~9~~8	370
199 — 210	395
211 — 222	420
Note If the sampling interval contains links made from more than one cast, extra break and mechanical tests are required so that tests are made on every cast.	

3.9 Mechanical tests

Existing paragraphs 3.6.25 to 3.6.29 have been renumbered 3.9.1 to 3.9.5.

3.9.6 A grain size determination must be made for the final product. The austenitic grain size for R3, R3S, R4, R4S and R5 is to be 6 or finer in accordance with ASTM E112 or equivalent grain size index in accordance to ISO 643. Measurements for circular sections are to be taken at surface, at one-third of the radius and centre for the base material, HAZ and weld.

3.9.7 Hardness tests are to be carried out on finished chain. The frequency and locations are to be agreed with LR. The recorded values are for information only and used as an additional check to verify that the heat treatment process has been stable during the chain production.

~~3.6.30~~ 3.9.8 The mass per unit length of stud link mooring cable is to comply with *Table ~~10.3.5~~ 10.3.6 Mass per unit length of stud link chain cable.*

Figure 10.3.2 Sampling of chain links has bee moved to below the new paragraph 3.9.8.

Table 10.3.5 Mechanical properties of chain cable materials has been moved and amended as shown below.

Table ~~10.3.4~~ 10.3.5 Mechanical properties of chain cable materials

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation % minimum	Reduction of area % minimum (*See* Note 3)	Charpy V-notch impact tests		
					Test temperature ºC	Average energy J minimum	Average energy flash butt weld J minimum
Note 1. The ratio of yield strength to tensile strength should ~~not exceed~~be 0,92 maximum unless specially approved.							
Note 2. Testing may be carried out at either 0°C or –20°C.							
Note 3. For cast fittings, the minimum values for reduction of area are to be 40% for Grades R3 and R3S and 35% for Grades R4, R4S and R5.							
Note 4. The aim maximum hardness for Grade R4S is to be HB330, and for Grade R5 is to be HB340.							

(*Part only shown*)

Table ~~10.3.5~~ 10.3.6 Mass per unit length of stud link chain cable

Nominal chain diameter (mm)	Mass per unit length 0,0219d^2 (kg/m)
210	966
222	1079

~~3.7~~ 3.10 Connecting common links or substitute links

Existing paragraphs 3.7.1 to 3.7.5 have been renumbered 3.10.1 to 3.10.5.

~~3.7.6~~ 3.10.6 Every connecting common link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated as detailed in *Table ~~10.3.2~~ 10.3.1 Test loads for mooring chain cables*.

~~3.7.7~~ 3.10.7 Every connecting common link is to be inspected in accordance with *Ch 10, ~~3.6 Testing of completed chain cables 3.6.5~~ 3.6 Proof load tests and non-destructive examination 3.6.3*.

~~3.7.8~~ 3.10.8 A second identical link is to be made for mechanical tests which are to be in accordance with *Ch 10, ~~3.6 Testing of completed chain cables 3.6.25~~ 3.9 Mechanical tests 3.9.1*. This test link is also to be inspected in accordance with *Ch 10, ~~3.7~~ 3.10 Connecting common links or substitute links ~~3.7.7~~ 3.10.7*.

~~3.7.9~~ 3.10.9 Each connecting common link is to be stamped ~~on the stud~~ with the identification marks listed in *~~Ch 10, 3.9 Identification 3.9.1~~ Ch 10, 3.11 Identification 3.11.1* plus a unique number for the link. The adjoining links are also to be stamped ~~on the studs~~.

~~3.8 Fittings for offshore mooring chain~~

~~3.8.1 Cable fittings are to be manufactured at an approved works. Fittings include, but are not limited to, shackles, triplates, end shackles, swivels, and swivel shackle~~

~~3.8.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of *Ch 4, 1 General requirements* or *Ch 5, 1 General requirements*, and *Ch 10, 3.8 Fittings for offshore mooring chain 3.8.3*. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.~~

~~3.8.3 Steel used for fittings must be manufactured by an approved process, and be killed and fine grain treated.~~

~~3.8.4 The austenite grain size of steel used for fittings must be 6 or finer as measured in accordance with ASTM E112.~~

~~3.8.5 Steel used for forgings or castings for grades R4S and R5 must be vacuum degassed.~~

~~3.8.6 For steel used for forgings or castings for grades R4S and R5 the following tests are to be carried out on each heat:~~
~~(a) Assessment and quantification of the level of non-metallic micro inclusions. These must be acceptable for the final product.~~
~~(b) Macro etching on representative sample, in accordance with ASTM E381 or equivalent, this must be free from any injurious segregation or porosity.~~
~~(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.~~
~~The results of these tests are to be supplied by the steel manufacturer, and the results are to be included in the final accessory documentation.~~

~~3.8.7 Fittings for chain are to be heat treated in accordance with procedures that have been approved by LR.~~

~~3.8.8 All fittings are to be manufactured to a manufacturing specification approved by LR, and provision is to be made for tensile and impact test specimens. The test samples are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see Table 10.3.4 Mechanical properties of chain cable materials*.~~

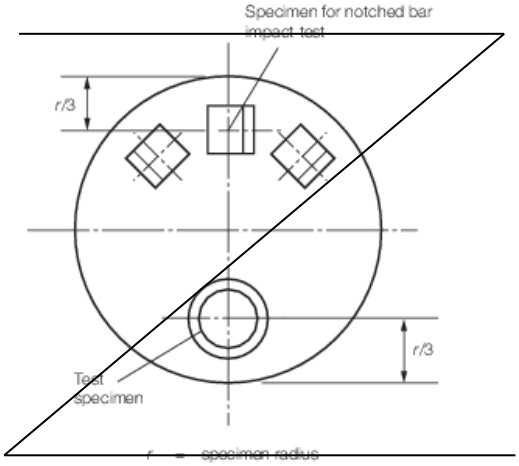


Figure 10.3.3 Sampling of steel bars, forgings and castings

3.8.9 For fittings for mooring chain, a batch is defined as fittings from the same steel-making heat that have been heat treated together in the same furnace.

3.8.10 Mechanical tests for fittings are to be taken from full size fittings that have been heat treated with the production batch they represent, and the tests are to be taken after the fitting has been proof load tested. It is not permitted to use separate representative coupons unless approved by LR in accordance with *Ch 10, 3.8 Fittings for offshore mooring chain 3.8.14*.

3.8.11 Forged shackle bodies and forged Kenter shackles are to have a set of three Charpy impact tests and a tensile test taken from the crown of the shackle. For smaller diameter shackles, where the geometry does not allow for the tensile test to be taken from the crown, this may be taken from the straight portion from the locations specified in *Figure 10.3.3 Sampling of steel bars, forgings and castings*, with the Charpy impact test specimens on the outside radius.

3.8.12 The test pieces for cast shackle bodies and cast Kenter shackles can be taken from the straight portion of the fitting from the locations shown in *Figure 10.3.3 Sampling of steel bars, forgings and castings*.

3.8.13 For fittings with complex geometries the locations of test pieces taken are to be approved by LR.

3.8.14 Where fittings are produced in small batches (less than 5) alternative testing may be approved; a proposal must be submitted in a written procedure for consideration.

3.8.15 Mechanical tests of pins are to be taken as shown in *Figure 10.3.4 Buffer and test piece location for pins* from the mid length of a sacrificial pin of the same diameter as the final pin. For oval pins, the diameter taken is to represent the smaller dimension. Mechanical tests may be taken from an extended pin of the same diameter as the final pin that incorporates a test prolongation and a heat treatment buffer prolongation, where equivalence with mid length test values have been established. The length of the buffer is to be at least equal to 1 pin diameter which is removed after the heat treatment cycle is finished. The test coupon can then be removed from the pin. The buffer and test are to come from the same end of the pin, as shown in *Figure 10.3.4 Buffer and test piece location for pins*.

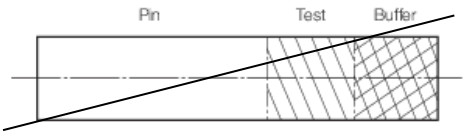


Figure 10.3.4 Buffer and test piece location for pins

3.8.16 Manufacturers intending to supply accessories in the machined condition (e.g. Kenter type shackles) are to submit detailed drawings for approval by LR.

3.8.17 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended, *see Table 10.3.2 Test loads for mooring chain cables*. Prior to this test, the accessories are to be shot or sand blasted to ensure that their surfaces are free from scale, paint or any other coating which could interfere with any subsequent inspection.

3.8.18 The appropriate breaking load as required by *Table 10.3.2 Test loads for mooring chain cables* is to be applied to at least one item out of every batch of up to 25, and this item is to be destroyed and not used as part of an outfit.

3.8.19 If the sample fails to withstand the breaking load without fracture, or in the event of failure of any other test, then the entire batch is to be rejected unless the cause of failure has been determined and it can be demonstrated that the condition causing failure is

~~not present in any of the other accessories in the batch. If this can be demonstrated then two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.~~

~~3.8.20 For very large fittings where the required breaking load is greater than the capacity of the testing machine and for individually produced accessories or accessories produced in small batches, proposals for an alternative method of testing will be given special consideration. All proposals for alternative testing methods are to be detailed in writing and submitted.~~

~~3.8.21 At least one accessory from each batch is to be checked dimensionally after proof load testing. The manufacturer is to provide a statement that the dimensions comply with the specified requirements.~~

~~3.8.22 The following tolerances apply of the unmachined dimensions of all fittings;~~
~~(a) nominal diameter plus 5 per cent, minus 0 per cent; and~~
~~(b) other dimensions plus or minus 2,5 per cent.~~

~~3.8.23 All accessories are to be subjected to close visual examination after proof load testing, particular attention being paid to machined surfaces and highly stressed regions. All accessories are also to be examined by magnetic particle or dye penetrant inspection and ultrasonic testing. All NDE is to be carried out in accordance with *Ch 10, 3.6 Testing of completed chain cables 3.6.9* and *Ch 10, 3.6 Testing of completed chain cables 3.6.10*. The manufacturer is to provide a statement that the non-destructive examination has been carried out with satisfactory results; this statement is to include reference to the techniques used and the operator's qualifications.~~

~~3.8.24 All testing is to be carried out to the satisfaction and in the presence of the Surveyor.~~

~~3.8.25 Fittings of increased dimensions or higher grade material may be used subject to approval by LR.~~

~~3.8.26 Where fittings with increased dimensions, or fittings of a higher material grade are included in an outfit:~~
~~(a) each item must be successfully tested at the required breaking load for the chain cable for which it is intended; and~~
~~(b) items of increased dimensions are so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load for the chain cable for which it is intended, and this has been verified by procedure tests.~~

~~3.9~~ 3.11 Identification

Existing paragraphs 3.9.1 and 3.9.2 have been renumbered 3.11.1 and 3.11.2.

~~3.9.3~~ 3.11.3 All identification marks are to be made on the studs for stud link chain or, on the outside of the straight part of the link, opposite the flash butt weld for studless chain, and are to be permanent and legible throughout the expected service life of the chain.

~~3.10~~ 3.12 Documentation

~~3.10.1~~ 3.12.1 A complete Chain Inspection and Testing Report, in booklet form, is to be provided by the chain manufacturer for each continuous chain length, and for each order for chain and fittings. It is to include all dimensional checks, test and inspection reports, non-destructive test reports, process records, photographs (for fittings, example photographs of components positioned in furnaces), as well as any non-conformity, together with corrective action and repair work.

Existing paragraphs 3.10.2 and 3.10.3 have been renumbered 3.12.2 and 3.12.3.

~~3.11~~ 3.13 Certification

Existing paragraphs 3.11.1 and 3.11.2 have been renumbered 3.13.1 and 3.13.2.

Existing Section 4 has been deleted in its entirety.

■ *Section 4*
Fittings for offshore mooring chain

4.1 Scope

4.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5 of fittings for offshore mooring chain. Fittings include, but are not limited to, shackles, triplates, end shackles, swivels, and swivel shackles.

4.1.2 Design of fittings must be to a recognised Standard, such as ISO1704, *see Figure 10.2.3 Enlarged link* to *Figure 10.2.9 Lugless shackle of the Kenter type*; alternatively, non-standard designs of fittings are to be subject to special consideration, and may require a fatigue analysis and tests to confirm relevant performance.

4.2 Manufacture

4.2.1 The materials from which the fittings are made are to be manufactured at works approved by LR, in accordance with the appropriate requirements of *Ch 4, 1 General requirements* or *Ch 5, 1 General requirements*, and the requirement in this Section. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

4.2.2 Steel used for fittings must be manufactured by an approved process, and be killed and fine grain treated.

4.2.3 The austenite grain size of steel used for fittings must be 6, or finer, as measured in accordance with ASTM E112 or equivalent grain size index in accordance to ISO 643. Measurements for circular sections are to be taken at one-third of the radius. Measurements for non-circular sections are to be taken at one-quarter of the thickness.

4.2.4 Steel used for forgings or castings for grades R4S and R5 must be vacuum degassed.

4.2.5 For steel used for forgings or castings for grades R4S and R5 the following tests are to be carried out on each heat:
(a) assessment and quantification of the level of non-metallic micro inclusions. These must be acceptable for the final product.
(b) macro-etching on a representative sample, in accordance with ASTM E381 or equivalent; this must be free from any injurious segregation or porosity.
(c) hardenability tests in accordance with ASTM A255 or equivalent.
The results of these tests are to be supplied by the steel manufacturer, and the results are to be included in the final fitting documentation.

4.2.6 Fittings for chain are to be heat treated in accordance with procedures that have been approved by LR.

4.3 Testing of fittings

4.3.1 For fittings for mooring chain, a batch is defined as fittings from the same steel-making heat that have been heat treated together in the same furnace.

4.3.2 All fittings are to be subjected to proof load tests, non-destructive examination, sample break load tests and sample mechanical tests after final heat treatment in the presence of a Surveyor. In addition to the requirements stated in this section, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

4.4 Proof and break load tests

4.4.1 All chain cable fittings, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended, *see Table 10.3.1 Test loads for mooring chain cables*. Prior to this test, the fittings are to be shot or sand blasted to ensure that their surfaces are free from scale, paint or any other coating which could interfere with any subsequent inspection.

4.4.2 The appropriate breaking load as required by *Table 10.3.1 Test loads for mooring chain cables* is to be applied to at least one item out of every batch of up to 25, and this item is to be destroyed and not used as part of an outfit.

4.4.3 If the sample fails to withstand the breaking load without fracture, or in the event of failure of any other test, then the entire batch is to be rejected unless the cause of failure has been determined and it can be demonstrated that the condition causing failure is not present in any of the other fittings in the batch. If this can be demonstrated, then two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

4.4.4 For very large fittings where the required breaking load is greater than the capacity of the testing machine and for individually produced fittings or fittings produced in small batches (less than five), proposals for an alternative method of testing will be given special consideration. All proposals for alternative testing methods are to be detailed in writing for approval and the following additional conditions may apply:
(a) Alternative testing is described in a written procedure and manufacturing specification.
(b) A finite element analysis is provided at the break load and demonstrates that the fitting has a safety margin over and above the break load of the chain.
(c) Strain age testing (in accordance with a procedure approved by LR) is carried out on the material grade produced to the same parameters at the time of qualification.
(d) If a fitting is of a large size that will make heat treating in batches unfeasible or has a unique design, strain gauges are to be applied during the proof and break load tests during initial qualification and during production. The strain gauge results from production are to be comparable with the results from qualification.

4.4.5 All fittings are to be subjected to close visual examination after proof load testing, particular attention being paid to machined surfaces and highly stressed regions.

4.4.6 Each fitting is subject to fluorescent magnetic particle or dye penetrant inspection on all surfaces and ultrasonic testing in accordance with a recognised Standard. As a minimum requirement surfaces must be free from:
- relevant linear indications exceeding 1,6 mm in transverse direction;
- relevant linear indications exceeding 3,2 mm in longitudinal direction;
- relevant non-linear indications exceeding 4,8 mm.

When required by LR, ultrasonic testing is to be carried out on 100 per cent of cast or forged fittings. The acceptance/rejection criteria established for the design is to be met.

4.4.7 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with *Ch 1, 5 Non-destructive examination*.

4.4.8 Fittings of increased dimensions or higher grade material may be used subject to approval by LR.

4.4.9 Where fittings with increased dimensions, or fittings of a higher material grade are included in an outfit:
(a) each item must be successfully tested at the required breaking load for the chain cable for which it is intended; and
(b) strain age properties must have been carried out on the material grade produced to the same parameters;
(c) strain gauges are to be applied during the break load test in the high stress locations to monitor that the strains stay within allowable limits.

For the purpose of this paragraph, items of increased dimensions are so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load for the chain cable for which it is intended, and this has been verified by procedure tests.

4.4.10 Weld repairs of finished fittings are not permitted.

4.5 Dimensional inspection

4.5.1 At least one fitting from each batch of up to 25 is to be checked dimensionally after proof load testing. The manufacturer is to provide a statement that the dimensions comply with the specified requirements.

4.5.2 The following tolerances apply to the unmachined dimensions of all fittings;
(a) nominal diameter plus 5 per cent, minus 0 per cent; and
(b) other dimensions plus or minus 2,5 per cent.

4.6 Mechanical tests

4.6.1 All fittings are to be manufactured to a manufacturing specification approved by LR, and provision is to be made for tensile and impact test specimens. The test samples are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see Table 10.3.4 Mechanical properties of chain cable materials*.

4.6.2 Mechanical tests for fittings are to be taken from full size fittings that have been heat treated with the production batch they represent, and the tests are to be taken after the fitting has been proof load tested. It is not permitted to use separate representative coupons unless approved by LR in accordance with *Ch 10, 4.6 Mechanical tests 4.6.6*. At least one fitting out of every batch of up to 25 is to be tested. Hardness tests are to be carried out on finished fittings. The frequency and locations are to be agreed with LR. The recorded values are for information only and used as an additional check to verify that the heat treatment process has been stable during the fitting production.

4.6.3 Forged shackle bodies and forged Kenter shackles are to have a set of three Charpy impact tests and a tensile test taken from the crown of the shackle. For smaller diameter shackles, where the geometry does not allow for the tensile test to be taken from the crown, this may be taken from the straight portion from the locations specified in *Figure 10.4.1 Sampling of steel bars, forgings and castings*, with the Charpy impact test specimens on the outside radius.

4.6.4 The mechanical test pieces for cast shackle bodies and cast Kenter shackles can be taken from the straight portion of the fitting from the locations shown in *Figure 10.4.1 Sampling of steel bars, forgings and castings*.

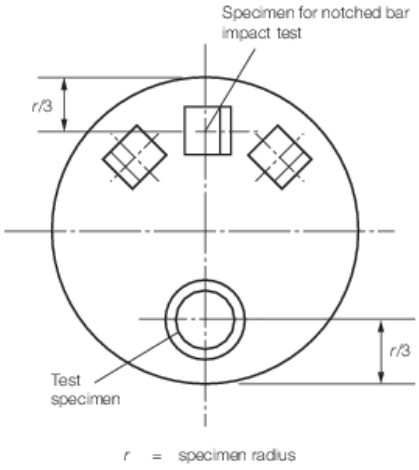


Figure 10.4.1 Sampling of steel bars, forgings and castings

4.6.5 For fittings with complex geometries the locations of mechanical test pieces taken are to be approved by LR. For non-circular sections, one-quarter of t (thickness) from the surface is considered appropriate. Rolled plates are to be tested to the standard to which they are produced.

4.6.6 Where fittings are individually heat treated or produced in small batches (less than five), alternative testing may be approved; a proposal must be submitted in a written procedure for consideration and the following additional conditions may apply:

(a) If separately forged or cast coupons are used, they are to have a cross-section and, for forged coupon, a reduction ratio similar to that of the fittings represented, and are to be heat treated in the same furnace and quenched in the same tank at the same time, as the actual forgings or castings. Thermocouples are to be attached to the coupon and to the fittings.

(b) If separately forged or cast coupons are agreed, it is to be verified by a procedure test that coupon properties are representative of fitting properties.

4.6.7 Mechanical tests of pins are to be taken as shown in *Figure 10.4.1 Sampling of steel bars, forgings and castings* from the mid- length of a sacrificial pin of the same diameter as the final pin. For oval pins, the diameter taken is to represent the smaller dimension. Mechanical tests may be taken from an extended pin of the same diameter as the final pin that incorporates a test prolongation and a heat treatment buffer prolongation, where equivalence with mid-length test values have been established. The length of the buffer is to be at least equal to 1 pin diameter which is removed after the heat treatment cycle is finished. The test coupon can then be removed from the pin. The buffer and test are to come from the same end of the pin, as shown in *Figure 10.4.2 Buffer and test piece location for pins*.

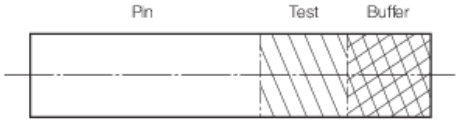


Figure 10.4.2 Buffer and test piece location for pins

4.6.8 Manufacturers intending to supply fittings in the machined condition are to submit detailed drawings for approval by LR. Machining of Kenter shackles must result in a fillet radius of a minimum of 3 per cent of the nominal diameter.

4.7 Identification

4.7.1 Each fitting is to be permanently marked with the following information:

(a) identification number, cast number or other marking which will enable the full history of the casting to be traced;

(b) manufacturer's name or trade mark;

(c) LR or Lloyd's Register, the abbreviated name of LR's local office, and number of certificate;

(d) personal stamp of Surveyor responsible for inspection;

(e) date of final inspection; and

(f) chain grade.

4.7.2 Where small casting/forging fittings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

4.8 Documentation

4.8.1 A complete Inspection and Testing Report in booklet form is to be provided by the manufacturer for each order. This booklet include all dimensional checks, test and inspection reports, NDE reports, process records and example photographs of components positioned in furnaces, as well as any non-conformity, corrective action and repair work.

4.8.2 Each type of fitting must be covered by separate certificates.

4.8.3 All documents, including reports and appendices, are to contain a reference to the relevant certificate number.

4.8.4 The manufacturer is responsible for storing all the documentation in a safe and retrievable manner for a period of at least 10 years.

4.9 Certification

4.9.1 Certificates are to be issued in accordance with *Ch 10, 3.13 Certification*.

Chapter 11
Approval of Welding Consumables

■ *Section 1*
General

1.2 Grading

(*Part only shown*)

Table 11.1.1 Welding consumable grades appropriate to structural and low temperature service and steel grades

Consumables grade	Suitable for steel grades (*see* Notes)			
1. Ship Grade Steels (*Ch 3, 2 Normal strength steels for ship and other structural applications* and *Ch 3, 3 Higher strength steels for ship and other structural applications*)				
3Y47	– – – –	– – – –	***EH40***	***EH47***
3Y47	–	–	***EH40***	***EH47***
2. High Strength Steels (*Ch 3, 10 High Strength quenched and tempered steels for welded structures*) *see* Note 3				
3Y69	AH62	AH69	–	–
3. Ferritic Low Temperature Service Steels (*Ch 3,6 Ferritic steels for low temperature service*) ~~(*Ch 3,6 Ferritic steels for low temperature service*)~~				
2 ¼ Ni	2 ¼ Ni	–	–	–

■ *Section 3*
Electrodes for manual and gravity welding

3.1 Grading

(*Part only shown*)

Table 11.3.1 Minimum low hydrogen approval requirements for manual and gravity electrodes

Approval grades	Low hydrogen grade required
1 ½ Ni	H15
2 ¼ Ni	H15
3 ½ Ni	H15

3.2 Deposited metal test assemblies

(*Part only shown*)

Table 11.3.2 Requirements for deposited metal tests (covered electrodes)

Grade (*see* Note 3)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2 (*see* Note 1)	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test Temperature °C	Average energy (*see* Note 2) J minimum
5Y69	690	770 - 940	17	–60	69
1 ½ Ni	375	~~460~~ 490 - 640	22	–80	34
2 ¼ Ni	375	490 - 640	22	–90	34
3 ½ Ni	375	~~420~~ 490 - 610	25	–100	34
5 Ni	~~375~~ 400	~~500~~ 540-740	25	–120	34
9 Ni	~~375~~ 400	~~600~~ 640-790	25	–196	34

Note 1. Single values are the minimum requirements.

Note 2. Energy values from individual impact test specimens are to comply with *Ch 11, 1.4 Approval procedures 1.4.3.*

Note 3. Grade 1Y is not applicable to SMAW consumables referenced in *Ch 11, 3 Electrodes for manual and gravity welding*.

3.3 Butt weld test assemblies

(*Part only shown*)

Table 11.3.3 Requirements for butt weld tests (covered electrodes)

Grade (*see* Note 3)	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Note 1) J minimum
				All positions (*see* Note 2)
5Y69	770 - 940	5	–60	69
1 ½ Ni	490	3	–80	27
2 ¼ Ni	490	3	–90	27
3 ½ Ni	~~450~~ 490	3	–100	27

3.4 Hydrogen test

3.4.1 The hydrogen gradings are specified in *Ch 11, 3.1 Grading 3.1.3*. The hydrogen grading required determines the method of testing permitted as shown in *Table 11.3.4 Permitted methods for obtaining low hydrogen grading*. ~~Where ISO 3690 is used as the testing method,~~ ~~three~~ Four test specimens are to be prepared and tested, and all ~~three~~ four hydrogen test results must be below the maximum value for the hydrogen mark required.

Table 11.3.4 Permitted methods for obtaining low hydrogen grading

Hydrogen Grade	Permitted Method
H15	ISO 3690 (Mercury or Thermal Conductivity Detector Method) ~~or Glycerine)(*See* Note)~~ Or Glycerine (*See* Note)
H10	ISO 3690 (Mercury or Thermal Conductivity Detector Method)
H5	ISO 3690 (Mercury or Thermal Conductivity Detector Method)
Note ISO method preferred.	

3.4.2 The minimum holding time at a given test temperature for Thermal Conductivity Method should be as shown in *Table 11.3.5 Temperature and minimum holding time*.

Table 11.3.5 Temperature and minimum holding time

Measuring Method		Test Temperature (°C)	Minimum Holding Time (h)
Thermal Conductivity Method (*see* Note 1)	Gas Chromatography	45	72
		150	6
Note 1. The use of hot carrier gas extraction method will be specially considered subject to verification of testing procedure to confirm that collection and measurement of the hydrogen occurs continuously until all the diffusible hydrogen is quantified.			

■ *Section 4*
Wire-flux combinations for submerged-arc automatic welding

4.1 General

(*Part only shown*)

Table 11.4.1 Minimum low hydrogen approval requirements for wire-flux combinations

Approval grade	'H' grade for Multi-run	'H' grade for Two-run
1 ½ Ni	H15	NR
2 ¼ Ni	H15	NR

4.3 Deposited metal test assemblies (multi-run technique)

(*Part only shown*)

Table 11.4.2 Requirements for deposit metal tests (wire-flux combinations).

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test Temperature °C	Average energy (*see* Note) J minimum
5Y69	690	770 - 940	17	–60	69
1 ½ Ni	375	~~460~~ 490 - 640	22	–80	34
2 ¼ Ni	375	490 - 640	22	–90	34
3 ½ Ni	375	~~420~~ 490 - 610	25	–100	34
5 Ni	~~375~~ 400	~~500~~ 540-740	25	–120	34
9 Ni	~~375~~ 400	~~600~~ 640-790	25	–196	34
Note Energy values from individual impact test specimens are to comply with *Ch 11, 1.4 Approval procedures 1.4.3.*					

4.4 Butt weld test assemblies (multi-run technique)

(*Part only shown*)

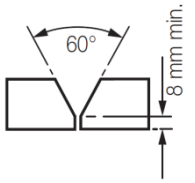
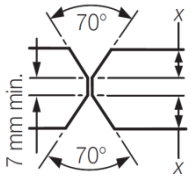
Table 11.4.3 Requirements for butt weld tests (wire-flux combinations)

Grade	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Notes 1 and 2) J minimum
1 ½ Ni	490	3	-80	27
2 ¼ Ni	490	3	-90	27
3 ½ Ni	~~450~~ 490	3	-100	27

4.6 Butt weld test assemblies (two-run technique)

Table 11.4.4 Butt weld assembly preparation

Plate thickness mm	~~Recommended diameter~~ Recommended edge preparation	Maximum diameter of wire mm
12,5		5

20-25		6
35-40		7

■ *Section 5*
Wires and wire-gas combinations for manual, semi-automatic and automatic welding

5.1 General

Table 11.5.1 Minimum low hydrogen approval requirements for wire and wire-gas combinations

Approval Grade	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for T technique
1 ½ Ni	H15	H15	NR
2 ¼ Ni	H15	H15	NR
3 ½ Ni	H15	H15	NR
5 Ni	NR (~~see~~ *see* Note 3)	NR	NR
9 Ni	NR (~~see~~ *see* Note 3)	NR	NR
Note 1. NR – Not required. Approval can be obtained when requested. Note 2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded. Note 3. Assumes use of an austenitic, non-transformable, filler material.			

■ *Section 7*
Consumables for use in one-side welding with temporary backing materials

7.1 General

(*Part only shown*)

Table 11.7.1 Minimum low hydrogen approval requirements for one-side welding with combinations including temporary backing material

Approval Grade	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for A technique
1 ½ Ni	H15	H15	NR
2 ¼ Ni	H15	H15	NR

7.2 Approval tests for manual (m), semi-automatic (S) and automatic multi-run (M) techniques

7.2.2 The thickness of test assembly ~~is to be~~ may be taken as 50 mm for Y47 base material.

7.2.3 The edge preparation and welding conditions are to be in accordance with the recommendations of the manufacturers. For the m and S techniques, the assembly is to be welded using, for the first run wire of the smallest diameter recommended by the manufacturer and, for the remaining runs, wire of the largest diameter to be approved. For the M technique any size wire as recommended by the manufacturer can be used.

7.3 Approval tests for high heat input automatic (A) techniques

7.3.3 The edge preparation and welding conditions are to be in accordance with the manufacturer's recommendations, and are to be reported to LR. The diameters of wires are to be in accordance with the recommendations of the manufacturer and are to be reported.

7.4 Annual tests

7.4.1 Annual tests are to consist of, at least, one butt weld test assembly, for each technique approved, using plates of 20 to 25 mm thickness. For the Y47 grade the thickness of plates may be taken as 50 mm.

■ *Section 8*
Consumables for welding austenitic and duplex stainless steels

8.3 Butt weld test assemblies

8.3.2 Butt weld assemblies are to be prepared for each position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the electrode/wire is to be approved.

Existing paragraphs 8.3.2 *to* 8.3.4 *have been renumbered* 8.3.3 *to* 8.3.5.

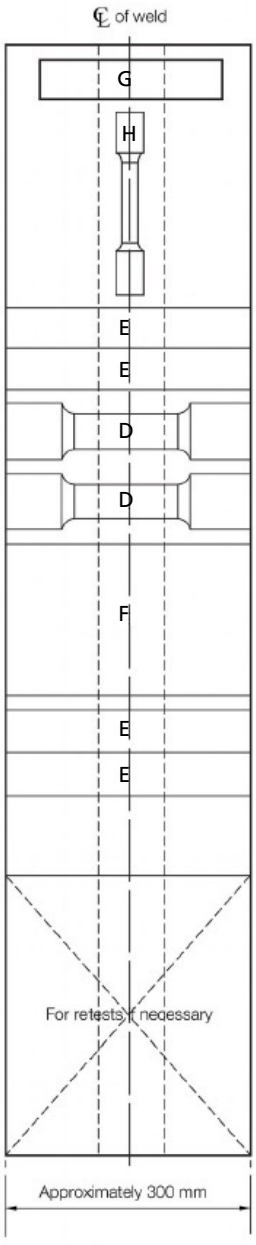
Chapter 12
Welding Qualifications

■ *Section 2*
Welding procedure qualification tests for steels

2.7 Destructive tests for steel butt welds

2.7.13 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in *Figure 12.2.14 Hardness testing locations for butt welds*, using a test load not in excess of 10 kg. For each row of indents, there are to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) ~~and~~, the base metal (both sides)~~.~~, and in addition, 2 indentations are required in the grain coarsened heat affected zone, one above and one below the hardness survey row. The recommended distance between indents is 1,0 mm, but the distance between indents should not be less than the minimum specified in ISO 6507~~/~~-1.

Existing Figure 12.2.8 Butt welds in plate and pipe over 750 mm diameter has been deleted.



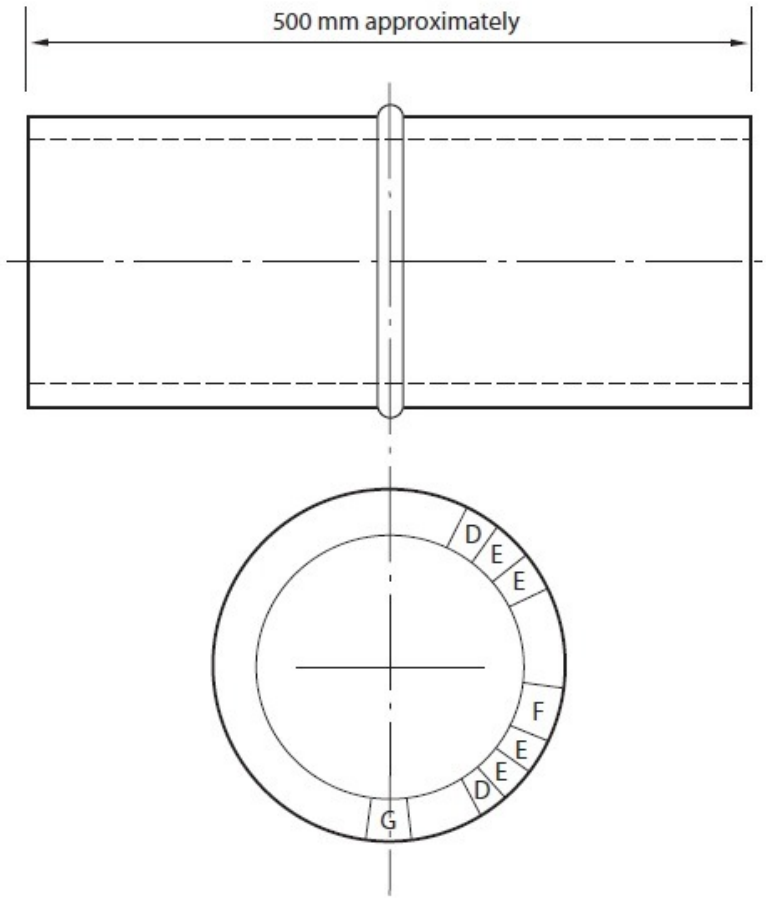
Test requirements
A Visual examination
B Surface crack detection

C 100 per cent radiographic examination (*see* Note1)
D Two transverse tensile tests
E Four bend tests
F Five sets Charpy V-notch impact tests
1 set notched at centre of weld
1 set notched at fusion line (FL)
1 set notched at FL + 2 mm
1 set notched at FL + 5 mm (*see* Note 2)
1 set notched at FL + 10 mm (if required)
G One macro specimen including hardness survey
H All weld metal tensile test (if required)

Figure 12.2.8 Butt welds in plate

Note 1 Radiographic examination may be replaced by ultrasonic examination for test assembly thickness of 8 mm or above.

Note 2 If required by *Figure 12.2.11 Locations of V-notch for butt weld of normal heat input (heat input ≤50 kJ/cm)* and *Figure 12.2.12 Locations of V-notch for butt weld of high heat input (heat input > 50 kJ/cm)*.



~~The diameter of the test piece is to be a minimum of *D*/2~~
~~where~~
~~*D* is the maximum diameter of the pipe to be welded in construction~~

Test requirements
A Visual examination
B Surface crack detection
C 100% radiographic examination (*see* Note1)
D Two transverse tensile tests
E Four bend tests~~.~~
~~Four side bends for thickness greater than 12 mm.~~
~~In other cases, two face and two root bends~~
F Four sets Charpy V-notch impact tests
1 set notched at centre of weld
1 set notched at fusion line (FL)
1 set notched at FL + 2 mm

1 set notched at FL + 5 mm ~~*(See Note)*~~ (*see* Note 2)

G One macro specimen including hardness survey

Figure 12.2.9 Butt welds in pipe ~~less than 750 mm diameter~~

Note 1 Radiographic examination may be replaced by ultrasonic examination for test assembly thickness of 8 mm or above.

Note 2 If required by *Figure 12.2.11 Locations of V-notch for butt weld of normal heat input (heat input ≤50 kJ/cm)* and *Figure12.2.12 Locations of V-notch for butt weld of high heat input (heat input > 50 kJ/cm)*.

2.12 Mechanical test acceptance criteria for steels

Table 12.2.2 Impact test requirements for butt joints (*t* ≤ 50mm) *see* Notes 1 and 2

Grade of Steel	Test temperature (^{0}C) *see* Note 4	~~Value of minimum energy absorbed (J),~~ Average energy (J) minimum, *see* Note 4		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A, *see* Note 3	20	47	34	34
B, *see* Note 3, D	0			
E	-20			
AH32, AH36	20			
AH32, AH36	0			
EH32, EH36	-20			
FH32, FH36	-40			
AH40	20		39	39
DH40	0			
EH40	-20			
FH40	-40			

Note 1. Steel ~~with yield strength greater than 390 N/mm^2~~ grade EH47 is not permitted in thickness less than 50 mm, *see* Note 2, *Table 3.3.1 Maximum thickness limits* in Chapter 3.

Note 2. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.

Note 3. For grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be a minimum of 27 J.

Note 4. For Naval ships both the test temperature and value of minimum energy absorbed are to be those specified for the parent material.

(*Part only shown*)

Table 12.2.3 Impact test requirements for butt joints (*t* > 50 mm) *see* Notes 1 and 2

Grade of steel	Test temperature (°C) *See* Note 4	~~Value of energy absorbed (J, min.),~~ Average energy (J) minimum, *see* Note 2		
		Manual or semi-automatic welded joints		Vertical upward, Vertical downward
		Downhand, Horizontal, Overhead	Automatically welded joints	

Note 1. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.

Note 2. For Naval ships, both the test temperature and value of minimum absorbed energy are to be those specified for the parent material.

Table 12.2.5 Welding procedure thickness approval range – Butt welds

Test thickness, ~~*see* Note 1~~ (*t* in mm)	Range approved	
	All multi-run butt welds and all fillet welds *see* Notes ~~3~~ 2 and ~~4~~ 3	All single-run or two-run ~~two-run~~ (T technique) butt welds
t≤3	*t* to 2*t*	0,7*t* to 1,1*t*
3<*t*≤12	3 to 2*t*	0,7*t* to 1,1*t*
12<*t*≤100	0,5*t* to 2*t* *see* Note ~~2~~ 1	0,7*t* to 1,1*t* *see* Note ~~5~~ 4
t>100	0,5*t* to 1,5*t*	0,7*t* to 1,1*t* *see* Note ~~5~~ 4

~~**Note** 1. Where the test plates have dissimilar thickness, the thickness, *t*, is to be based on the minimum thickness for butt welds and the maximum thickness for fillet welds.~~

Note ~~2~~ 1. Subject to a maximum limit of 150mm.

Note ~~3~~ 2. For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval of the individual welding process.

Note 4 3. For vertical down welding, the test piece thickness, *t*, is the upper limit of the range of application.

Note ~~5~~ 4. For processed with heat input over 5,0kJ/mm, the upper limit of the range of approval is to be 1,0*t*.

(*Part only shown*)

Table 12.2.6 Diameter range approved

Diameter used for test, *see* Note 1	Range of diameters approved
D≤25 mm	0,5*D* to 2*D*
D>25 mm	>0,5*D*, *see* Note 2

Note 1. *D* is the outside diameter of the pipe or the smallest side dimension of rectangular hollow section.

Note 2. Lower diameter range limited to 25 mm minimum.

Note 3. Qualification given for plates also covers pipes when the outside diameter is greater than 500 mm or when the diameter is greater than150 mm welded in the Downhand (D) or Horizontal (X) positions.

2.15 Range of approval

(*Part only shown*)

2.15.8 **Range of material types:**

(a) ~~A qualification test performed on one strength level of steel may be used to weld all similar materials with the same or lower specified minimum yield stress with the exception of the two-run (T) or high welding heat input (A) techniques where acceptance is limited to the strength level used in the test. Similarly, a qualification test performed on a steel with one toughness level may be considered acceptable for welding all similar materials with the same or three two toughness grades lower specified minimum toughness level.~~ For normal and higher strength steels, for each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested. For each toughness grade, welding procedures are considered applicable to the same and two lower strength levels as that tested with the exception of the two-run (T) or high welding heat input (A) techniques where acceptance is limited to the strength level used in the test.

(e) For weldable C and C-Mn steel castings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel castings does not qualify other delivery conditions and vice versa. ~~Dissimilar materials. Where a qualification test has been performed using dissimilar materials, acceptance is to be limited to the materials used in the test.~~

(f) Dissimilar materials. Where a qualification test has been performed using dissimilar materials, acceptance is to be limited to the materials used in the test.

■ *Section 5*
Welder qualification tests

5.6 Range of approval

(*Part only shown*)
Table 12.5.2 Welder qualifications materials groupings

Material Group	Material description	Typical LR Grades	Rules for Material references
WQ 03	High strength fine grained, Normalised or quenched, or Tempered structural steels (2,0 – 5% Ni, with Re> 360 N/mm^2)	AH to FH40 to 69 LT-AH to LT-FH40 1 ½, 2 ¼, 3 ½ Ni steels and castings U3, R3, R3S and R4	*Ch 3, 3 Higher strength steels for ship and other structural applications* and *Ch10 Equipment for Mooring and Anchoring* *Ch3, 6 Ferritic steels for low temperature service* *Ch3, 6 Ferritic steels for low temperature service Ch4, 7 Ferritic steel castings for low temperature service* and *Ch6, 4 Ferritic steel pressure pipes for low temperature service* ~~*Ch3, 9 Bars for welded chain cables*~~and *Ch 3, 9 Bars for welded chain cables* and *Ch10 Equipment for Mooring and Anchoring*

Chapter 13
Requirements for Welded Construction

■ *Section 1*
General welding requirements

1.6 Forming and bending

1.6.2 Where hot forming is employed ~~or during cold forming where the material is subjected to a permanent strain exceeding 10 per cent or formed to a diameter to thickness ratio less than 10, tests are required to be performed to demonstrate that the material properties remain acceptable.~~ the manufacturer is required to demonstrate that the forming procedure is compliant with a recognised National or International Standard or shall demonstrate by appropriate qualification tests that the material properties remain acceptable in the 'as formed' condition.

1.6.3 Materials that are cold formed, such that the permanent strain exceeds 10 per cent, or formed to a diameter to thickness ratio less than 10, are to be subjected to a subsequent softening heat treatment in accordance with the material manufacturer's recommendations, unless it is demonstrated by testing that the material properties are acceptable in the 'as formed' condition.

Existing paragraphs 1.6.3 *and* 1.6.4 *have been renumbered* 1.6.4 *and* 1.6.5.

■ *Section 5*
Specific requirements for pressure piping

5.3 Heat treatment after bending of pipes

5.3.1 After forming and bending of pipes, the heat treatments specified in this Section are to be applied unless the pipe material manufacturer specifies ~~of~~ or recommends other requirements.

5.3.2 Generally, hot forming is to be carried out within the normalising temperature range. When carried out within this temperature range, no subsequent heat treatment is required for carbon and carbon/manganese steels. For alloy steels, 1Cr ½ Mo, 2 ¼ Cr 1Mo and ½ Cr ½ Mo ¼ V, a subsequent ~~tempering~~ stress relieving heat treatment in accordance with *Ch 13, 1.16 Post-weld heat treatment* at the temperatures and times specified in ~~*Table 13.5.3 Heat treatment after bending of pipes*~~ *Table 13.5.4 Post-weld heat treatment requirements for piping* is required, irrespective of material thickness.

~~5.3.5 Heat treatment should be carried out in accordance with *Ch. 13, 1.16 Post-weld heat treatment*.~~

~~5.3.6~~ 5.3.5 Bending procedures and subsequent heat treatment for other alloy steels will be subject to special consideration.

5.4 Post-weld heat treatment

Table 13.5.4 Post-weld heat treatment requirements for piping

Material Grade	Thickness for which post-weld heat treatment is required	Soak temperature(°C) *see* Note2	Soak period
Carbon and carbon/manganese grades: 320, 360, 410, 460, 490	Over 30 mm	580-620°C	1 hour per 25 mm of thickness, 320, 360, 410, 460, 490 minimum 1 hour
1Cr ½ Mo	Over 8 mm	620-660°C	1 hour per 25 mm of thickness, minimum of 1 hour
2 ¼ Cr1Mo	All	650-690°C	1 hour per 25 mm of thickness, minimum of 1 hour
½ Cr ½ Mo ¼ V	All, *see* Note 1	670-720°C	1 hour per 25 mm of thickness, minimum of 1 hour
Note 1. Heat treatment may be omitted for thicknesses up to 8 mm and diameters not exceeding 100mm and minimum service temperature 450°C provided that welding procedure tests have demonstrated acceptable properties in the as welded condition. Note 2. For materials supplied in tempered condition, the post weld heat treatment temperature is to be at least 20°C less than the material tempering temperature.			

Chapter 14
Plastics Materials and other Non-Metallic Materials

■ *Section 3*
Testing procedures

3.7 Tests for specific materials

Table 14.3.1 Tests for unreinforced thermoplastic resins

Test	Standard
Tensile properties	ISO 527-2:~~1993~~
Flexural properties	ISO 178:~~2001~~
Water absorption	ISO 62:~~2008~~
Temperature of deflection under load	ISO 75~~-2~~:2004
Compressive properties	ISO 604:~~2002~~

Table 14.3.2 Tests on unreinforced cast thermoset resin specimens

Test	Standard
Tensile properties	ISO 527-2:~~1993~~
Flexural properties	ISO 178:~~2001~~
Water absorption	ISO 62:~~2008~~
Temperature of deflection under load	ISO 75-2:~~2004~~
Compressive properties	ISO 604:~~2002~~
Note *1.* ISO 62:~~2008~~ - where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:~~2008~~ for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water. Note *2.* ISO 527-2:~~1993~~ - tensile properties are to be measured using extensometry.	

Table 14.3.3 Tests on laminate specimens

Test	Standard
Tensile properties	ISO 527-4:~~1997~~
Flexural properties	ISO 14125:~~1998~~
Compressive properties	ISO 604:~~2002~~
Interlaminar shear	ISO 14130:~~1997~~
Water absorption	ISO 62:~~2008~~
Glass content	ISO 1172:~~1996~~
Note *1.* ISO 62:~~2008~~ - where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:~~2008~~ for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water. Note *2.* ISO 527-4:~~1997~~ - tensile properties are to be measured using extensometry. Note *3.* Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.	

3.8 Structural core materials

3.8.1 Initially, the core shear strength and modulus are to be determined by ISO 1922:~~2001~~ or ASTM C273/C273M. Test sandwich panels are then to be prepared and subjected to four-point flexural tests to determine the apparent shear properties according to ASTM C393/C393M:~~06~~ (short beam) at two representative thicknesses (i.e. 15 mm and 30 mm). Testing is to be carried out at ambient temperature and at 70°C. The following requirements are to be observed:

Table 14.3.4 Tests on end-grain balsa

Test	Standard
Density	ISO 845:~~2006~~
Tensile properties	ASTM C297/C297M:~~04~~ Test speed = $\frac{Thickness}{10}$ mm/min
Compressive properties	ISO 844:~~2007~~ Test speed = $\frac{Thickness}{10}$ mm/min
Shear properties	ISO 1922:~~2001~~ Test speed = 1 mm/min

3.9 Machinery chocking compounds

Table 14.3.5 Tests for machinery chocking components

Test	Standard
Izod Impact Resistance	ISO 180~~-2000~~ Unnotched
Barcol hardness	ASTM D2583~~-07~~ or ~~BS 2782 part 10 Method 1001~~ BS EN 59
Compressive strength	ISO 604~~:2002~~
	Test speed = 1 mm/min
Water absorption	ISO 62~~:2008~~ Method 1
	25 mm x 20 mm cylinder
	(to constant weight)
Oil absorption (light machine)	ISO 175~~:1999~~
	25 mm x 20 mm cylinder
	(to constant weight)
Temperature of deflection under load	ISO 75-2 Method A

Chapter 15
Corrosion Prevention

■ *Section 2*
Coatings

2.4 Seawater ballast tank coatings

2.4.8 The following tanks shall not be considered to be dedicated seawater ballast tanks and shall therefore be exempted from the application and requirements of the Performance Standard for Protective Coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers (resolution MSC.215(82)), provided the coatings applied in the tanks described in *Ch 15, 2.4 Seawater ballast tank coatings 2.4.8(b)* and *Ch 15, 2.4 Seawater ballast tank coatings 2.4.8(c)* below are confirmed by the coating manufacturer to be resistant to the media stored in these tanks and provided such coatings are applied and maintained according to the coating manufacturer's procedures.

(a) Ballast tank identified as 'Spaces included in Net Tonnage' in the 1969 ITC Certificate;
(b) Seawater ballast tanks in passenger vessels also designated for the carriage of grey water or black water;
(c) Seawater ballast tanks in livestock carriers also designated for the carriage of the livestock dung.

2.8 Other internal tanks

2.8.1 Other internal tanks not covered by the above shall include those listed in *Ch15, 2.4 Seawater ballast tank coatings 2.4.8* and ~~may~~ shall include those intended for the storage of, for example: black water; grey water; potable or made water, permanent ballast tanks, fuel tanks, etc.

2.8.3 Selection of any coating system for such spaces shall be ~~based upon the intended contents, the position of the space within the hull, the expected frequency of use in service and the coating manufacturer's recommendations~~ confirmed by the coating manufacturer to be resistant to the media stored in these tanks and shall be applied and maintained according to the coating manufacturer's procedures.

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